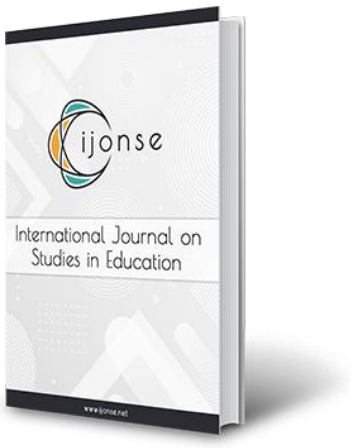

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Enhancing STEM Education in Rural Schools through Play Activities: A Scoping Review

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Abstract

Rural schools face unique challenges in providing high-quality Science, Technology, Engineering, and Mathematics (STEM) education due to limited resources, geographical isolation, and often a lack of access to specialised teachers. To engage children and enhance learning results in such contexts, educators and researchers frequently turn to creative strategies like play activities. This scoping review examines the role of play activities in enhancing STEM education within rural schools, addressing the unique challenges posed by resource constraints and geographical isolation. The review synthesises existing literature to identify gaps and chart pathways for future research. Utilising the PRISMA methodology and Arksey and O'Malley's framework. 278 articles published between 2018 and 2024 from the ERIC, Semantic Scholar, and ProQuest databases were reviewed; 275 were screened for eligibility. However, fourteen articles that satisfied the inclusion criteria were reviewed. Play activities have been shown to have a significant positive impact on students' motivation, engagement, collaboration, and recall of STEM concepts. As a result, they offer a practical solution to the challenges associated with STEM education in rural areas. The review underscores the importance of evidence-based strategies to foster equitable and effective STEM education in rural settings. This scoping review significantly contributes to the expanding literature on innovative pedagogical approaches in STEM education. It offers valuable insights for educators, policymakers, and researchers dedicated to enhancing STEM learning experiences in rural schools through play activities.

Introduction

In recent years, there has been an increasing acknowledgment of the pivotal role of Science, Technology, Engineering, and Mathematics (STEM) education in preparing students for the multifaceted challenges of the 21st century (Osadchyi et al., 2019). Beyond imparting essential knowledge and skills, STEM education cultivates critical thinking and problem-solving prowess and nurtures creativity. However, delivering high-quality STEM education in rural schools encounters distinctive hurdles due to resource constraints, including limited funding, inadequate infrastructure, and a need for more qualified educators. Geographical remoteness, socioeconomic

inequalities, and a dearth of exposure to STEM-related opportunities exacerbate these challenges (Lin et al., 2023). Play activities may be incorporated into the STEM curriculum as a creative way to address these issues. "Play activities" in education refer to intentional, enjoyable, and often surprising activities intended to motivate students to actively explore, try new things, and learn by play. Children may explore, create, and learn independently with these engaging, hands-on, and open-ended activities (Koeners & Francis, 2020). Teachers may create immersive learning experiences that grab students' interest, encourage active participation, and improve their recall of STEM topics by utilizing the natural influence of play. Additionally, play activities encourage group learning, experimentation, and problem-solving, which fits well with modern STEM education frameworks' inquiry-based and hands-on learning paradigms (Romero et al., 2012).

For these reasons, a scoping review systematically explores the existing literature on using play activities to enrich STEM education in rural schools. The study attempts explicitly to identify gaps in the existing literature and map out future research directions in STEM teaching in rural settings. This scoping assessment aims to clarify the potential of play-based approaches in overcoming the unique challenges faced by rural schools in providing successful STEM education through a critical examination of existing research.

National efforts to promote excellence and equality in STEM education would be substantially aided by the use of the data collected from this study to create effective strategies and programs to enhance STEM education for kids in rural areas. It summarises the data supporting the advantages of play activities in STEM education, draws attention to the particular difficulties faced by rural schools, and provides useful suggestions for educators and policymakers based on the findings of the scoping review. It also encourages further research on the long-term effects and scalable models of play-based STEM instruction, with a particular emphasis on guiding rural students toward STEM careers. Thus, it bridges a gap in the literature by focusing on the underexplored integration of play activities into STEM education in rural schools.

Methodology

The Preferred Reporting Items for Systematic Reviews (PRISMA) criteria were followed in reporting this scoping review (Ne'matullah et al., 2022; Zaid et al., 2022). This scoping study was carried out utilising the methodological approach developed by Arksey and O'Malley (2005): research questions; (2) relevant studies identified; (3) relevant studies selected; (4) data charting; and (5) collecting, summarising, and reporting the findings.

Identifying Research Question

Table 1 shows the fundamental research questions created based on the research objectives of the Population-Concept-Context (PCC) framework.

Table 1. Research Questions and Objectives based on PPC Framework

Sn	Research Question	Research Objectives
1.	How have past studies on play-based	To explore past studies' temporal and

Sn	Research Question	Research Objectives
	activities in STEM education in rural schools within the last seven years been distributed?	geographical distribution and settings (last seven years).
2.	What research designs have been employed in past studies on play-based activities in STEM education in rural schools?	To determine the research methods/designs used in past studies.
3.	What are past studies' primary objectives regarding enhancing STEM education through play activities?	To analyse past studies' research purposes/aims regarding enhancing STEM education through play activities.
4.	What specific skills are targeted or developed in past studies on play-based STEM education in rural schools?	To investigate the specific skills targeted or developed in past studies.
5.	What are past studies' reported findings on play-based activities in STEM education in rural schools?	To report the findings of past studies on the impact of play-based activities in STEM education in rural schools.

Identifying Relevant Studies

The second step is to identify the relevant studies. The search strings utilised were generally used to have the most results from the relevant studies. Table 2 shows the search strings involved. Employing sophisticated Boolean operators, particularly "OR" and "AND," facilitated refining and broadening the search parameters. This methodical use of Boolean logic strengthened the search process's resilience by guaranteeing accuracy and thoroughness in locating pertinent content. Table 2 provides a detailed description of the search terms and phrases used in this attempt.

Table 2. Search String/Keyword

Database	Search string/Keyword
ERIC ProQuest Semantic Scholar	(Play Activities OR funs) AND (Rural Schools OR remote schools) AND (STEM education)

Study Selection

The selection of studies is the third phase. The search's inclusion criterion is specified in this phase. Following brainstorming and discussion with the members of the research team, the findings of the discussed criterion are shown in Table 3. These preset standards provide precise instructions for research to be included, making it easier to find pertinent material in a methodical manner. After applying these criteria, studies that meet the specified qualifications are meticulously catalogued using the Preferred Reporting Items for Systematic Reviews and Meta-

Analyses (PRISMA) flow chart. This methodical approach not only enhances the transparency of the review process but also reinforces its rigour and reliability.

Table 3. Inclusion and Exclusion Criterion

Inclusion Criteria	**Exclusion Criteria**
Articles published from 2018 onward	Article published before 2018
Related to Rural Schools	Not related to Schools
Text in the English language	Other languages
Full text available	Without full text

Data Charting

Data charting is the fourth phase. The first author creates a chart and has it approved by the senior author after discussing with the research members which publications should be included in the data.The chart was created using the following research components: author, publication year, article title, nation of origin, setting, design type, participant, study purpose, end findings, and recommendations for the future.

Collate, Summarise, and Report Results

The last step involves compiling, summarising, and reporting the findings. Once the chart presented by the first author is finished, the study participants are called upon once more to examine and edit the data and offer further suggestions. This is to ensure that the supplied data meets the previously mentioned standards and study goals.

Findings and Discussion

Through three carefully chosen databases—the Education Resources Information Centre (ERIC), Semantic Scholar, and ProQuest—the search turned up 278 articles. Figure 1 illustrates that 164 titles were taken from the ProQuest database, while 08 titles were found in the ERIC database. One hundred six titles were retrieved from the Semantic Scholar database during identification. Three duplicate titles were removed from the 278 articles, leaving 275 titles for eligibility screening. Moreover, 245 titles were disqualified from the screening based on their abstracts and titles. As a result, 30 titles had their eligibility evaluated by data extraction. A total of sixteen titles were excluded because they did not fit the requirements for inclusion. Eight titles had a do with IT, two titles were about the internet, two titles were about urban dynamics, one title was about environmental science, and three titles focused explicitly on leadership. As a result, just 14 titles were chosen to be reviewed in this edition. Figure 1 shows the scoping review flow diagram.

Distribution of Past Studies

The articles included in this review were published from 2018 to 2024, with different distributions across the years. The first studies were conducted in 2018 by Halim et al. (2018) and Blotnicky et al. (2018), and Fraser et

al. (2019) followed in 2019. Additional contributions emerged in 2020 from Ardianti et al. (2020) and Qiao and Zhou (2020), with subsequent studies in 2021 by Morris et al. (2021) and in 2022 by Gavari-Starkie et al. (2022). The year 2023 saw a notable increase with studies by (Casado-Mansilla et al. (2023), Lin et al. (2023), Zhou et al. (2023), Sirengar et al. (2023), and Husain et al. (2023)). Finally, in 2024, Le Thi Tuyet et al. (2024) and Chen et al. (2024) were found.

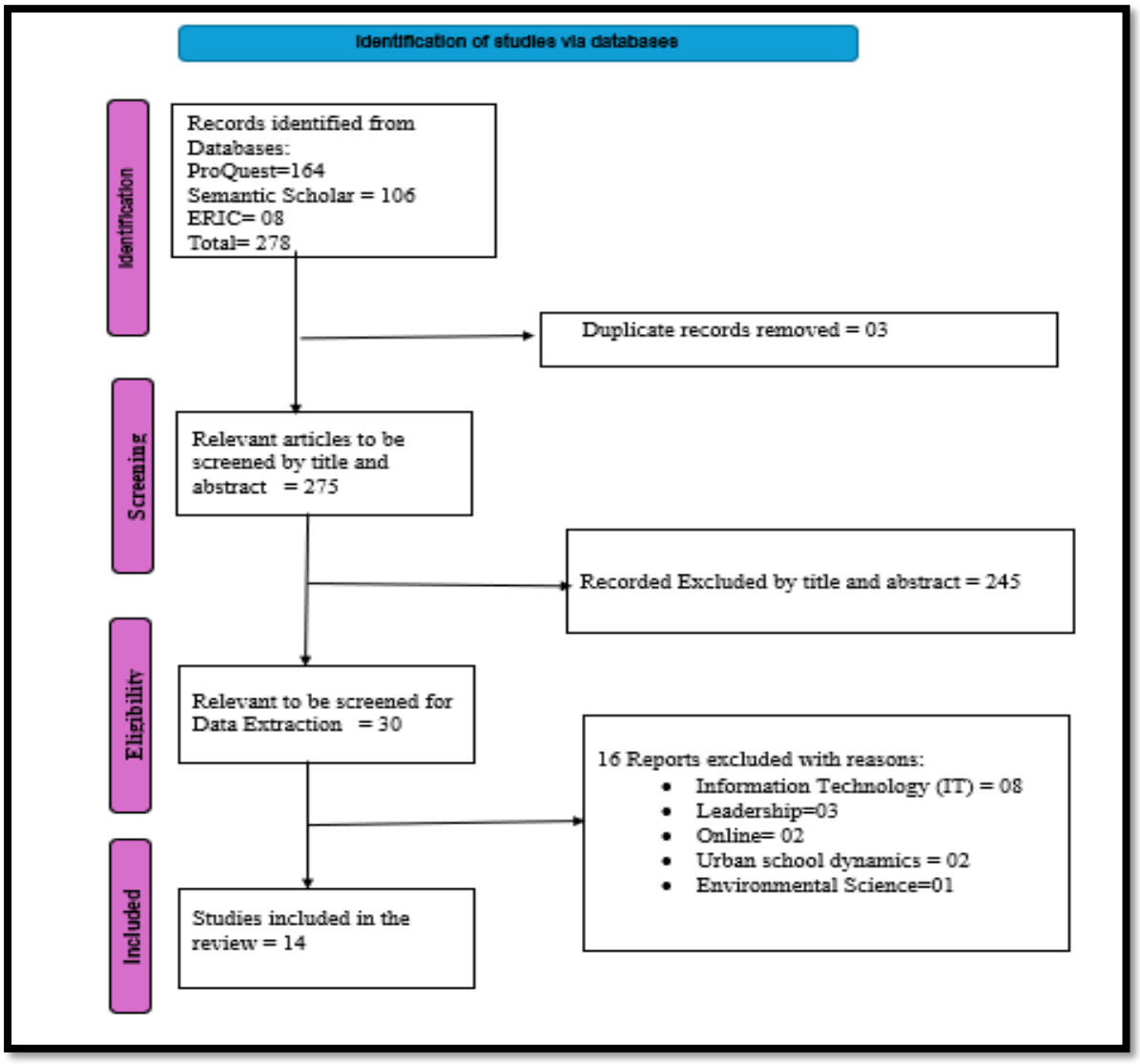

Figure 1. Flow Diagram for a Scoping Review

The literature reveals an uneven geographic distribution in research on play activities within STEM education in rural schools. While there is a growing body of literature in this field, studies predominantly focus on specific regions or countries. Gavari-Starkie et al. (2022), for instance, emphasised how rural education in Spain is marginalised in STEAM initiatives. Morris et al. (2021), on the other hand, focused on gifted pupils in Australia. Research from the United Arab Emirates (Husain et al., 2023), China (Qiao & Zhou, 2020), and Indonesia (Ardianti et al., 2020) shows a growing interest in incorporating STEM education into rural settings. However, there is still room for improvement in terms of a holistic global approach.

Research Designs Employed in Past Studies

Various research approaches are used to investigate play-based activities within STEM education in rural schools, according to this study's examination of 14 publications. According to research by Fraser et al. (2019), Gavari-Starkie et al. (2022), and Zhou et al. (2023), qualitative approaches have been widely used to explore perceptions and experiences. On the other hand, quantitative methods have also gained popularity, especially for evaluating how STEM programs affect student outcomes. Research by Husain et al. (2023), Lin et al. (2023), Siregar et al. (2023), Chen et al. (2024), Bloctnicky et al. (2018), Ardianti et al. (2020), Qiao and Zhou (2020), and others demonstrates this pattern.

Moreover, Morris et al. (2021) demonstrate how a mixed-methods approach incorporating qualitative and quantitative data has been used to provide a thorough viewpoint. Furthermore, other methodologies such as quasi-experimental designs, secondary data extraction, and instrument development and validation have been applied in studies by Casado-Mansilla et al. (2023), Le Thi Tuyet et al. (2024), and Halim et al. (2018), respectively.

Primary Objectives of Past Studies

Previous research examining how play activities might improve STEM education has sought to achieve a number of goals. To boost student engagement and enhance information retention, interactive learning is recommended by Morris et al. (2021) and Qiao & Zhou (2020). Ardianti et al. (2020) focused on using mixed STEM learning approaches to develop critical thinking and problem-solving abilities. Fraser et al. (2019) and Gavari-Starkie et al. (2022) highlight the necessity of specialised educational approaches to close the gap between urban and rural communities.To maintain interest in STEM subjects, studies by Halim et al. (2018), Blotnicky et al. (2018), Siregar et al. (2023), Husain et al. (2023), and Chen et al. (2024) examine how STEM education affects students' career ambitions. Zhou et al. (2023) and Casado-Mansilla et al. (2023) focus on developing and evaluating integrated STEM programs using innovative approaches such as solution-based design processes and remote experimentation.Additionally, Lin et al. (2023) examine STEM teachers' perceptions regarding which educational goals should be emphasised through integrative STEM education. Le Thi Tuyet et al. (2024) analyze scientific publications on STEM education in elementary schools across Southeast Asian countries, proposing directions for future research to enhance training effectiveness.

No	Title	Reference	Country of origin	Design	Participant	Aims of the study	Result	Remarks
1.	Sustainability through STEM and STEAM Education Creating Links with the Land for the Improvement of the Rural	(Gavari-Starkie et al., 2022)	Spain	Qualitative	N/A	The main objective of the study is to consider rural education as a possible solution to rural	The results show that STEM studies have continued uninterrupted until today, although the interest	Most of the research has been carried out in urban areas and rural education is invisible to STEAM programs. It is

	World					depopulation in “empty Spain”, creating links with the land between the rural population and its location in the territory	generated in the scientific community has been irregular. According to this report, the supply of ICT and STEM graduates from upper secondary education is insufficient to meet the demand. Very few young people are studying STEM subjects. Entry requirements and dropout rates are high and women’s participation is low. It	proposed to correct this situation, as the intrinsic characteristics of rural education favor the successful development of STEAM programs in gender equality.
2.	Using Local Rural Knowledge to Enhance STEM Learning for Gifted and Talented Students in Australia	(Morris et al., 2021)	Australia	multi-method study	26 students’ years 7 and 8 in a rural school.	To explore a group of gifted lower secondary students’ engagement and experiences in a STEM programme designed around a local rural knowledge model as reported by Avery (2013)	The research found that the local rural knowledge model enhanced students’ engagement in STEM learning and they felt that they retained knowledge better as a result of the authentic learning experience.	
3.	The impact of	(Ardianti et	Indonesia	Quantitative	27 students	The research	The result of	

the use of STEM education approach on the blended learning to improve student's critical thinking skills.	al., 2020)	research with a pretest-posttest control group design	found that blended learning with STEM education approach improved better critical thinking of students than conventional learning. The limitation of this study is that during online learning, students with less digital literacy still need assistance from teachers at the beginning of learning. The contribution in this study lies in a unique framework that is in the process of delivering knowledge using blended learning embedded the STEM education approach for high school physics	this research shows that using blended learning with STEM education approach gives better influence to improve student's critical thinking skill and learning interest than conventional learning.

					lessons in the rural area.	
4.	STEM education in primary schools of Southeast Asian countries: An analysis of scientific publications in the Scopus database from 2000 to 2022	(Le Thi Tuyet et al., 2024)	Southeast Asian countries	secondary data extracted		The results of the study show that publications on STEM education in elementary schools in Southeast Asian countries started to be studied from 2008 and have been increasing rapidly; scientific papers published in some high-impact factor journals; the countries with the most publications are not necessarily Southeast Asian countries, mainly in the Americas, Europe, Asia, with Indonesia being the only Southeast Asian country in the top-5 countries with the most publications

							on this research trend. Based on the analysis, the article proposes some directions for STEM education research in elementary schools in Southeast Asian countries to achieve high effectiveness in training at elementary schools.
5.	Research on the Integration of STEM Education into the Rural Elementary School Science Curriculum: An Example from Rural Elementary Schools in Western China	(Qiao & Zhou, 2020)	China	Quantitative method	fifth-grade students of Jiujiang elementary school in Shuangliu District, 200 students of comparable learning levels were divided into control and experimental groups of 100 each.	This research integrates STEM education into rural elementary school science courses to explore whether STEM courses are effective in improving students' knowledge and ability, asking: Are STEM courses better than traditional science courses in improving students'	The experimental data reveals that the teaching practice of STEM used in this study was effective in improving the science curriculum knowledge and ability of elementary school students in rural China and had advantages over the traditional science curriculum.

						knowledge and abilities?		
6.	Triple helix components supporting STEM education to increase future STEM careers in the United Arab Emirates	(Husain et al., 2023)	United Arab Emirates	Quantitative methods approach	Government Cluster Sample • Six schools, 123 STEM leaders/teachers. • 361 middle to high school students. • 101 parents. Industry Cluster Sample • 101 middle school to university level students. • 53 leaders/teachers. University Cluster Sample • 110 students and 54 leaders/teachers.	The main purpose of the study is to investigate the stakeholder's perceptions and responses on STEM education programs, STEM careers, and triple helix components (THC) in the UAE.	The results from this study showed that the stakeholders had positive perceptions on STEM education programs, STEM careers, and THC.	Further investigation is needed to gain more information about the significant differences in perspectives between and within the stakeholder clusters.
7.	Students' interest in Science, Technology, Engineering, and Mathematics (STEM) based on parental education and gender factors	(Siregar et al., 2023)	Indonesia	Quantitative methods approach	150 secondary school students at Simanosor Julu, Medan, Indonesia.	This study aims to identify the differences and interactions of student interest in STEM based on parental education and gender.	The results of data analysis based on the mean score indicated that there are differences in students' interest in STEM-based on gender	It is recommended that there are additional study more deeply the STEM interests of students based on: (a) social-economic status,

							and parental education. The mean score of male students, based on parental education at the university level, is higher than female students.	(b) rural and urban schools, (c) the relationship between the two variables, and (d) involves students with more numbers.
8.	STEM learning opportunities and career aspirations: the interactive effect of students' self-concept and perceptions of STEM professionals	(Chen et al., 2024)	Hong Kong	Quantitative methods approach	608 primary and secondary school students from Hong Kong	this study examined whether and how the influences of media consumption and school STEM learning opportunities on career aspirations would be mediated by perceptions of STEM professionals, and whether the mediation effect would be conditional on students' self-concept	Results revealed that the students' positive perceptions of STEM professionals were positively associated with their career aspirations and mediated the links from media consumption and school opportunities to career aspirations. In addition, this mediated pathway depended on STEM self-concept, such that perceptions of STEM professionals were only linked with STEM career aspirations	The findings of this study suggest the need to pay attention to STEM perceptions and self-concept interaction while designing and implementing learning activities to connect a diversity of students with STEM careers. It is not only important to foster students' self-concept, but also to enrich their knowledge of diverse occupations, so as to help diversify their perceptions that being professionals in these fields is desirable and attainable, and to eventually

							for adolescents with average or high levels of self-concept.	inspire more student engagement and participation in STEM.
9.	Engaging solution-based design process for integrated STEM program development: an exploratory study through autoethnographic design practice	(Zhou et al., 2023)	Qualitative	This study adopts an autoethnographic methodology recommended by Munro (2011) to address a systematic understanding of SBDP's usefulness in developing integrated STEM programs. However, qualitative content analysis method to examine the gathered text data.		we explore how the optimised SBDP can inform (i) The design skills and mindsets of DBP for integrated STEM education, and (ii) The instructional processes for constructing and implementing integrated STEM tasks involving design models	As found in this study, a unique feature of the Solution-based DBP is that it relates to the processes of thinking and reasoning—highly cognitive and logical; its application requires the skilled operation of 3D printing-based digital fabrication. Additionally, we demonstrated a Solution-based DBP, combined with 3D printing-based digital fabrication, and providing teachers with a structural blueprint for developing integrated STEM programs.	Thus, valuable experience in relevant teaching and learning appears to cultivate students necessary knowledge for their future employment and career, so they appear ready to address the STEM-related issues that impact both humans and the natural environment.
10.	STEM education goals in the	(Lin et al., 2023)	Taiwan	Quantitative methods approach	A total of 645 valid survey	This study examined which	The findings revealed that STEM	Thus, further exploration is required to

	twenty-first century: Teachers' perceptions and experiences				responses were collected and then analysed	particular STEM education goals should be emphasised through a survey questionnaire.	teachers generally had positive attitudes and high levels of acceptance toward implementing the 17 proposed STEM education goals through integrative STEM education. However, the proposed goal of "cultivating students' entrepreneurial capabilities" received lower scores and should not be used at the secondary level	determine whether the proposed STEM education goals can also fulfil and reflect the demands of K–6 STEM education. Finally, future research should explore the perceptions of teachers with regard to STEM education goals at the levels of kindergarten to primary school, primary school, and tertiary education to develop more systematic and better-articulated.
11.	Remote experiments for STEM education and engagement in rural schools: The case of project R3	(Casado-Mansilla et al., 2023)	Spain	Quasi-Experiment design		The main objective is that from the local analysis (the Project has only been conducted in Spain) it might be possible to draw conclusions of a global nature that might be extrapolated	the European Union with similar socio-demographics. Initial results are in the direction of certifying that student achievement and satisfaction are higher in rural than in urban environment	decision-makers such as policy-makers, education departments, and any other institution responsible for education should consider remote experimentation as a means to democratize access to science. It is essential for

						to other countries in the European Union with similar socio-demographics.	s.	these decision-makers and teachers to take note of the findings of this article, not only because of its low cost per pupil, ease of maintenance, and lack of technological deployment but also for the reasons stated earlier.
12.	Responding to the Demands of the STEM Education Agenda: The Experiences of Primary and Secondary Teachers from Rural, Regional and Remote Australia	(Fraser et al., 2019)	Australia	Qualitative	Primary and secondary teachers from rural, regional, and remote Australia.	To investigate the perceptions of teachers regarding the issues impacting effective STEM education in rural, regional, and remote Australia and to explore the strategies they use to overcome these barriers, thereby building the confidence and capacity of STEM teachers.	The study identified several challenges faced by teachers in rural, regional, and remote areas in implementing effective STEM education. These included limited resources, professional development opportunities, and support. However, teachers employed various strategies to overcome these barriers, such as collaborative efforts,	The paper suggests potential solutions to address the challenges faced by schools in rural, regional, and remote Australia. These recommendations include increasing access to resources, providing targeted professional development, and fostering collaboration between schools and external organizations to support the effective teaching of STEM.

							seeking external support, and utilizing innovative teaching methods.	
13.	Factors influencing interest in STEM careers: An exploratory factor analysis.	(Halim et al., 2018)	Malaysia	Instrument development and validation	354 middle secondary school students (14 years of age).	This study aimed to develop an instrument of STEM career interest.	This shows that environmental, self-efficacy, perception of STEM careers and interest in STEM careers all play an important role in influencing students' decision in choosing their careers and fields of study	For future research, these identified factors need to undergo CFA analysis to enhance the validity and reliability of the developed instrument. Factors identified in this study serve as a guide in constructing a model of interest in STEM careers.
14.	A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students	(Blotnicky et al., 2018)	Atlantic Canada	Quantity	1448 students in grades 7 and 9 was drawn from public schools in Atlantic Canada	To explore students' knowledge of science and mathematics requirements for science, technology, engineering, and mathematics (STEM) careers. Also explored were their mathematics self-efficacy (MSE), their future career interests,	The results of this study show that students in middle school have a limited STEM career knowledge with respect to subject requirements and with respect to what sort of activities these careers involve. Furthermore, students with low MSE have a	Our data thus support the need to improve access to knowledge to facilitate students' understanding of STEM careers and the nature of STEM work. Exposure of students to STEM careers can enhance their interest in pursuing careers involving science, technology,

	their preferences for particular career activities, and their likelihood to pursue a STEM career	declining interest in STEM careers.	engineering, and mathematics.

Specific Skills Targeted or Developed

Past studies have targeted a range of skills through play-based STEM education. Critical thinking is a recurrent focus, as evidenced by the work of Ardianti et al. (2020). Other targeted skills include scientific knowledge and abilities, highlighted by Qiao and Zhou (2020), and practical skills related to digital fabrication and design, as seen in Zhou et al. (2023). In order to promote long-term interest and involvement in STEM disciplines, several research also seek to improve students' views of STEM occupations and self-efficacy (Chen et al., 2024; Siregar et al., 2023).

Morris et al. (2021) highlight the importance of play STEM activities in fostering creativity and problem-solving abilities. Halim et al. (2018) and Blotnicky et al. (2018) highlighted factors influencing students' interest in STEM careers, including environmental factors, self-efficacy, and knowledge of STEM careers. Zhou et al. (2023) explored the development of design skills and cognitive abilities through a Solution-based Design Process (SBDP) integrated with STEM education. Gavari-Starkie et al. (2022) focused on creating links with the land to promote sustainability through STEM and STEAM education in rural Spain.

Past Studies' Reported Findings on Play-Based Activities in STEM Education in Rural Schools

The evaluated research on play activities in STEM teaching in rural schools yields several important conclusions.

Challenges in Rural Areas

Socioeconomic, cultural, and pedagogical challenges that prevent students from accessing and succeeding in STEM fields are among the difficulties facing STEM education in rural areas. Key difficulties are highlighted by Gavari-Starkie et al. (2022), including high dropout rates, especially among female students, strict entrance requirements, and low involvement and knowledge in STEM topics due to a lack of resources and role models. These difficulties highlight the structural disadvantages that rural students have, which are made worse by gender inequality that has its roots in social and cultural issues. Addressing these issues through targeted interventions, including policy reforms, enhanced educational resources, and mentorship, is essential to create a more equitable and inclusive educational environment in rural areas.

Enhanced Engagement and Knowledge Retention

examines how teaching methods, particularly play and STEM-related activities, impact students' memories and experiences. This is required because to the ways in which different teaching philosophies may foster greater understanding, critical thinking, and a sustained interest in coursework.The importance of engagement and information retention in educational research and practice is emphasised by the results of several studies. For example, Qiao & Zhou (2020) in China and Morris et al. (2021) in Australia point out that including play activities that are based in STEM education or are culturally appropriate significantly increases student involvement. These activities improve memory and learning by connecting academic content to students' interests and real-world uses. Because these activities align the curriculum with students' interests and practical applications, they improve learning and retention of information.

Ardianti et al. (2020) from Indonesia offer more proof, showing that students' critical thinking abilities are significantly improved when STEM methods and digital manufacturing techniques are combined. This technique differs from standard instructional methods, which could not encourage as deep a cognitive engagement or engage pupils as much.

Overall, the Enhanced Engagement and Knowledge Retention sub-theme underscores the importance of innovative and contextually relevant teaching methods. These strategies engage students more effectively and enhance their ability to retain and apply knowledge, thereby contributing to a more robust and comprehensive learning experience.

Teacher Challenges and Collaborative Strategies

This review highlights educators' multifaceted challenges in delivering effective STEM education, particularly in rural contexts. These challenges often include inadequate resources, limited professional development opportunities, and the isolation experienced by teachers in remote areas. Understanding these challenges is crucial for developing targeted interventions to enhance educational outcomes.Studies like Fraser et al. (2019) reveal that teachers in rural settings grapple with significant constraints, such as a lack of resources and insufficient professional development. By identifying these issues, researchers and policymakers may more effectively address the factors influencing the calibre of STEM education. It is also critical to emphasize how crucial teamwork is to overcome these obstacles. Teachers in remote areas can collaborate with schools, communities, and organisations to access shared resources, knowledge, and support systems. In order to create sustainable improvements in STEM education delivery, this collaborative framework is necessary.

Designing focused policies and procedures is aided by knowledge of these issues and solutions. For instance, developing collaborations for resource sharing and assisting with professional development programs will significantly reduce the challenges experienced by teachers in distance areas, ultimately leading to better STEM student motivation, according to Fraser et al. (2019), and associated studies show that improving STEM education in rural areas requires overcoming challenges and using collaboration. This strategy addresses contemporary challenges and forms fundamental long-term academic performance.

Gender Disparities and Play Activities Approaches

Siregar et al. (2023) draw attention to gender differences in STEM interest in Indonesia and stress the role that parental education levels have in these variations. They contend that in order to alleviate these inequities, play-based techniques might be extremely important. By using playful, interactive ways to improve STEM course accessibility and engagement, these initiatives help close the gender gap and foster an inclusive learning environment. Play Activities and Gender Inequalities Strategies are crucial because they highlight how play activities may be used to explicitly target and lessen gender disparities in STEM disciplines in addition to increasing STEM interest generally.

Remote Experimentation and Policy Support

In STEM education, remote experimentation has become a game-changing tool, especially in rural locations where traditional laboratories and resources may be few. Casado-Mansilla et al. (2023) claim that remote experimentation is an inexpensive means of filling in educational gaps since it exposes students to scientific methods and practical experience that they may not otherwise have. To exploit the advantages of this Its emphasis on both government support and technical innovation serves to highlight this. According to Casado-Mansilla et al., while remote experimentation may democratise STEM education, its success mainly rests on legal, solid, and technological foundations. In support of this, Husain et al. (2023) show how strategic educational activities may have a major impact on future STEM career development by fostering favourable stakeholder perceptions of STEM education. According to their results, remote experimentation and other instructional tactics are improved when stakeholders including educators, legislators, and community leaders support and appreciate STEM education. Therefore, to fully realise the promise of remote experimentation in furthering STEM education, legislative support and stakeholder participation are essential.

Integrative STEM Education Goals

Lin et al. (2023) from Taiwan explore secondary teachers' acceptance of integrative STEM education goals and the challenges in implementing entrepreneurial skills. The study shows that teachers who support integrative STEM principles face difficulties applying entrepreneurial skills in the classroom. These challenges include a lack of resources, poor training, and institutional restrictions. Because it highlights the disparity between academic objectives and practical application, this sub-theme is significant. In order to improve student outcomes by better preparing them for future occupations, improve policy and practice, and increase the efficacy of STEM education, these concerns must be addressed.

Role of Students' Perceptions

Hong Kong-based Chen et al. (2024) highlight how students' opinions of STEM professionals influence their career goals and the importance of treatments that help students develop a positive self-concept. In Malaysia, Halim et al. (2018) identify the factors that influence students' interest in STEM jobs and provide interventions to

improve rural students' views of STEM careers, self-efficacy, and environmental factors. Blotnicky et al. (2018) in Atlantic Canada highlight the need of improving middle school students' comprehension of STEM career requirements in order to boost their interest and engagement in STEM fields. Additionally, Le Thi Tuyet et al. (2024) build on Indonesia's expanding research contributions by recommending future study areas to improve STEM education efficacy in Southeast Asian elementary schools.

Summary

Prior research has demonstrated the significant potential for play-based STEM education in rural schools to enhance students' engagement, career aspirations, and critical thinking skills. These findings emphasise the value of applying local expertise, providing authentic educational opportunities, and overcoming challenges including a lack of financing and support. The creation of more inclusive and successful STEM education initiatives that are adapted to the unique requirements of rural schools is supported by this foundation.

Research Gaps and Future Directions

Several research gaps were found in this evaluation, including methodological, theoretical, practical, and geographic ones.Firstly, previous studies primarily focused on developed countries (Blotnicky et al., 2018; Fraser et al., 2019; Casado-Mansilla et al., 2023; Chen et al., 2024; Qiao & Zhou, 2020; Morris et al., 2021; Gavari-Starkie et al., 2022), while developing countries, such as Malaysia, were largely neglected.Second, most previous research used quantitative approaches (qiao & zhou, 2020; Husain et al., 2023; Siregar et al., 2023; Chen et al., 2024; Lin et al., 2023; Blotnicky et al., 2018; Ardianti et al., 2020). In order to give a more thorough understanding, future research should use a mixed-methods approach. Thirdly, the existing literature has focused predominantly on interdisciplinary education, historical context, and development, whereas play-based learning and STEM careers have received limited attention (Gavari-Starkie et al., 2022).Additionally, most prior studies concentrated on urban students, with rural students receiving less attention (Ardianti et al., 2020; Le Thi Tuyet et al., 2024; Husain et al., 2023; Siregar et al., 2023; Chen et al., 2024; Zhou et al., 2023; Lin et al., 2023; Halim et al., 2018; Blotnicky et al., 2018).Lastly, prior findings show that environmental factors, self-efficacy, perceptions of STEM careers, and interest in STEM careers significantly influence students' career choices and fields of study (Halim et al., 2018). Blotnicky et al. (2018) revealed that middle school students need more knowledge of STEM career requirements and the activities involved. Furthermore, students with low mathematics self-efficacy (MSE) exhibit a declining interest in STEM careers.Conversely, another study found that students' positive perceptions of STEM professionals were positively associated with their career aspirations, mediating the links between media consumption, school opportunities, and career aspirations (Chen et al., 2024). Therefore, prior results indicate inconsistencies that require resolution in more research.

Conclusion

The conclusion of this research emphasises how play activities in rural schools from 2018 to 2024 have a significant potential to enhance student motivation, engagement, critical thinking skills, and career objectives in

STEM education. The study shows a diverse variety of research methods and an unequal geographic distribution, using mixed-method, qualitative, and quantitative approaches to examine different aspects of play-based STEM education. The difficulties that are specific to rural regions such as poor student enthusiasm and involvement, resource limitations, and gender inequality are highlighted by key results. However, integrating play activities grounded in local knowledge or STEM frameworks has proven effective in enhancing student engagement, knowledge retention, and critical thinking skills. Studies from Australia, China, and Indonesia demonstrate that these approaches can significantly improve learning experiences and outcomes. Collaborative teaching strategies, teacher support, and government aid are also necessary for addressing the barriers in STEM education in rural locations. Remote experimentation and integrated STEM education goals are two examples of promising approaches that the paper presents for democratising and improving STEM education in a range of contexts. These findings demonstrate the necessity of inclusive, resource-supported STEM education programs designed especially to satisfy the particular needs of rural schools.

Building on local knowledge, providing authentic learning experiences, and fostering positive perceptions of STEM careers, these programs can play a crucial role in bridging educational disparities and promoting sustained interest in STEM fields among rural students.

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